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SUMMARY OF THE WORKSHOP ON ULTRAVIOLET COSMIC BACKGROUND RADIATION*

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INTRODUCTION

Ultraviolet cosmic background radiation is of interest to relativistic astrophysicists because of the possibility that part of the observed background may arise from emission from intergalactic matter or from processes in the early universe.

Radiation from intergalactic gas might include bremsstrahlung,[1,2] highly redshifted Lyman α and helium 304 line radiation, or recombination radiation.[3-10] Paresce *et al.* have made the important point that helium 304 radiation would be quite strongly attenuated by neutral hydrogen in ordinary galaxies.[11] Line[12] or continuum[13,14] emission might be present from primeval galaxies. De Rújula and Glashow point out that slowly moving massive neutrinos might decay to produce line radiation in the ultraviolet,[15] and Stecker[16] and Kimble *et al.*[17] have examined observations of the ultraviolet cosmic background from this point of view.

Reviews of cosmic ultraviolet background radiation by Davidsen *et al.*[18] and Paresce and Jakobsen[19] have emphasized that the observations that exist are very discordant. Bowyer (this workshop) emphasized that the discord is in absolute intensity, in spatial structure on the sky, and in spectral shape. Our goal in the present workshop was to try to understand the reasons for these disagreements and to examine critically our understanding of the various sources of "noise" that interfere with the detection of any diffuse extragalactic emission that may exist.

The relationship of the ultraviolet background radiation to the x-ray (Fabian, this volume) background is shown in FIGURE 1. It is ironic that the ultraviolet background, which is four orders of magnitude brighter than the x-ray background, is much less well determined! The relationship of the ultraviolet background to the EUV background and an excellent summary of the discordant ultraviolet observations at high galactic latitudes are given in Figure 1 of Paresce and Jakobsen.[19]

FIGURE 2 presents a picture of the universe from the point of view of those who study ultraviolet background radiation, with emphasis on the various sources of noise that can affect the measurements. The altitudes of various observing platforms are also indicated.

I shall now discuss the situation regarding the various forms of natural noise and instrumental noise and difficulties, following which I shall briefly discuss the observations.

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AIRGLOW

Huffman and his colleagues (FIGURE 3) find an unexpected strong (thousands of photons (cm^2 s ster Å)$^{-1}$, called "units" hereafter) time-variable night airglow at 1550 Å, looking down from an altitude of 160–260 km.[20] The spectrum that they observe is shown in FIGURE 4.

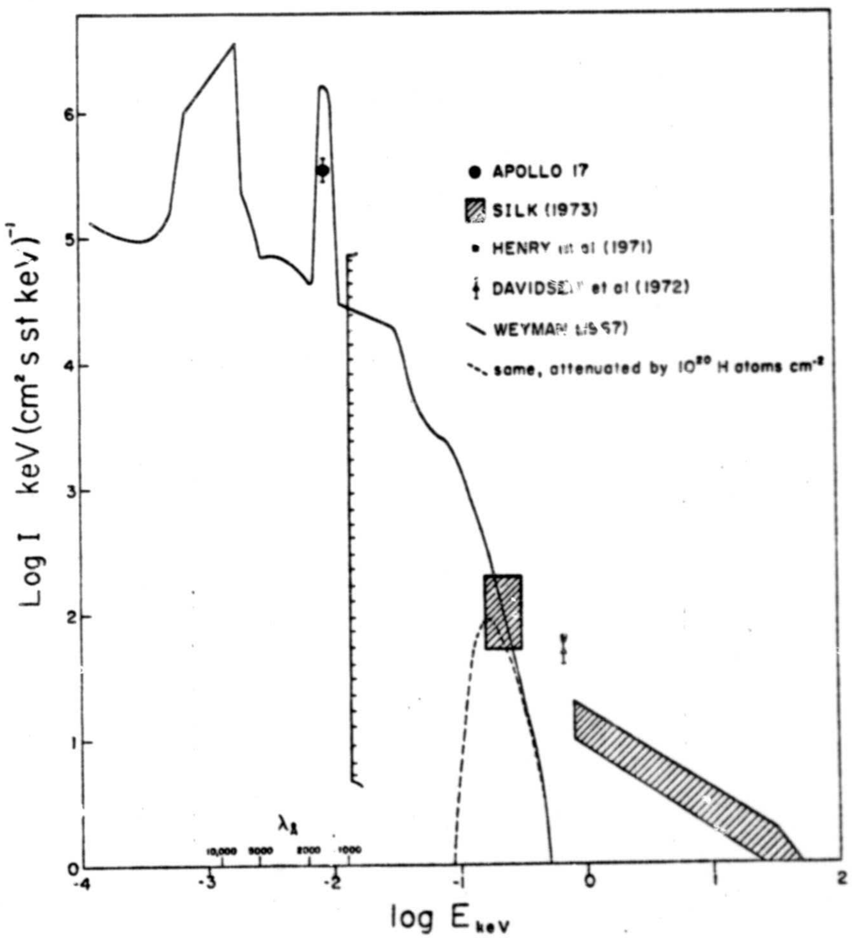

FIGURE 1. This is an overview, from Henry *et al.*,[20] of the relationship of high galactic latitude ultraviolet background radiation to the well-known x-ray background (Fabian, this volume). The thin line represents radiation from a hypothetical hot ionized intergalactic medium.[4] The broad bump represents highly redshifted Lα radiation, while the narrower bump in the far-ultraviolet part of the spectrum represents highly redshifted He 304 radiation. The position in wavelength of these emissions is very model-dependent. Paresce *et al.* have shown that the He 304 emission would be attenuated by gas in galaxies.[11] The point marked Apollo 17[20] gives the lowest value for the high latitude ultraviolet background that has been found.

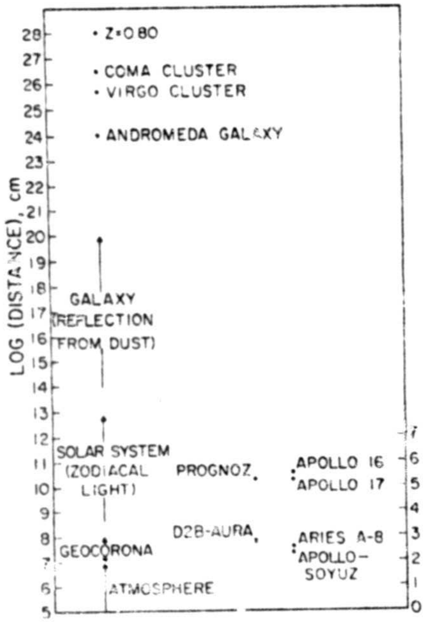

FIGURE 2. A picture of the universe from the point of view of studies of far-ultraviolet background radiation. The right-hand scale gives the logarithm of the distance in km. The altitudes of a variety of observing platforms are indicated. The Apollo 17 observations were made on trans-earth coast, while the Apollo 16 observations were made from the surface of the moon. The Prognoz spacecraft was in a highly elliptical orbit. The Aries A-8 was a sounding rocket; its maximum altitude is indicated. Atmospheric and geocoronal emissions can affect observations, depending on the altitude of observation. Scattered sunlight and the light of galactic-plane B stars scattering from high-latitude dust are also potential problems. Numbers of distant galaxies are inevitably in the field of view, representing yet another source of "noise." At a redshift $z = 0.8$, 912 Å radiation appears at 1650 Å. Radiation from more distant normal galaxies would not affect measurements of the background at wavelengths shorter than this.

Zodiacal Light

A priori, one would not expect zodiacal light to be a serious problem in the far ultraviolet, simply because the sun is relatively cool and, therefore, does not provide much ultraviolet light that could scatter off solar system dust. The existing observations are in serious disagreement, as shown in Figure 5 of Maucherat-Joubert *et al.*, who claim a positive detection at 1800 Å that is well above what is predicted from the

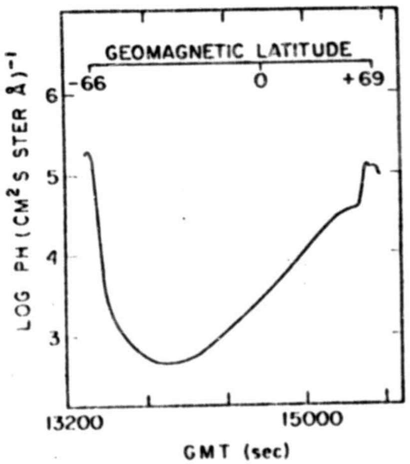

FIGURE 3. Strong airglow at 1550 Å is seen looking downward from 160–260 km.[26]

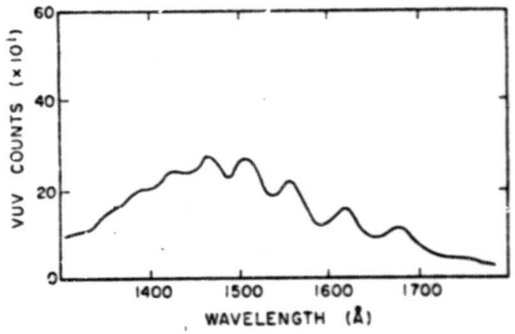

FIGURE 4. The spectrum of the night airglow, looking down from 160–260 km.[20]

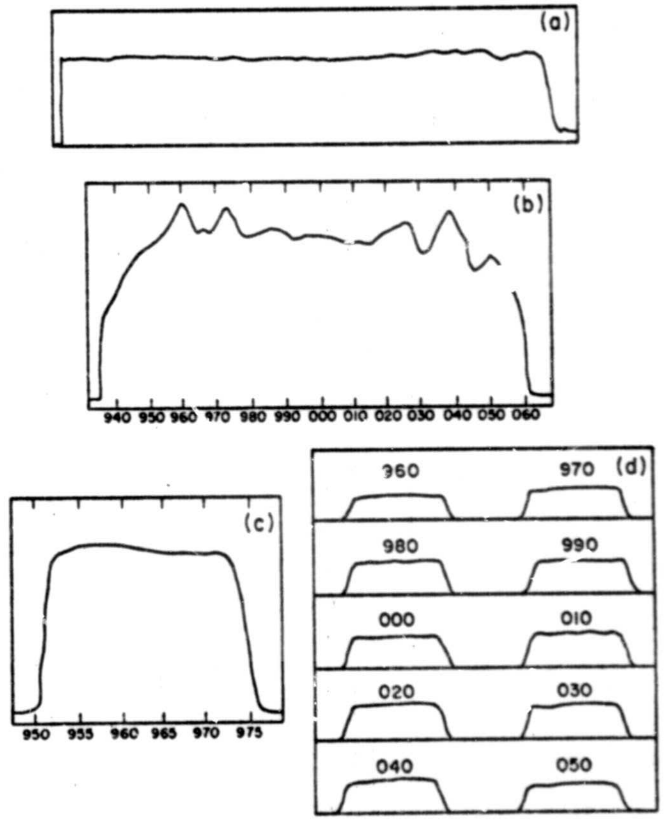

FIGURE 5. Details of the Aries A-8 absolute calibration[17]: (a) lack of variation in response as the angle of the calibration beam through the spectrometer is varied, (b) variation of photocathode response along its length, (c) variation of photocathode response across its width at its center, (d) variation of photocathode response measured recently at many locations along the length of the photocathode. We conclude that the system response to diffuse sources is essentially the same as its response to point sources.

solar spectrum.[21] In contrast, the positive detection at the same wavelength by Pitz and his colleagues is 1.5 orders of magnitude lower and is in good agreement with the relative solar spectrum,[22] but appears to be well beyond the capabilities of current optical systems.

Interstellar Dust

It is certain that interstellar dust is present even at the highest galactic latitudes.[23] Sandage has observed the visible light of galactic plane stars scattering from high-latitude dust.[24] Henry *et al.* detect no ultraviolet signal at moderate latitudes beyond what can be accounted for by direct starlight.[25] They conclude that if the albedo of the interstellar grains is high,[26] then the grains must be extremely strongly forward scattering ($g > 0.9$). (The conventional scattering parameter, g, is zero for isotropic scattering and negative for backscattering.) They estimate the stellar contribution using a calibrated star catalogue, which should be adequate but is not ideal. Subsequently,[27] using the TD-1 stellar observations[28] to correct their data, they are only able to conclude that $g > 0.7$. This is because the TD-1 observations were available only as an integrated function of galactic latitude, and a few bright stars at moderate latitudes poison the test. If $g = 0.7$, then the residual flux that is observed at the highest latitudes[29] might be due to the light of galactic plane B stars scattering from dust; if $g = 0.9$, then the residual flux is surely extragalactic. Witt reports that $g = 0.25$ on the basis of observations of nebulae.

Stars

Henry integrated the brightness of stars in common star catalogues,[31] calibrated to the far ultraviolet.[32] He found that the expected surface brightness due to all stars with $|b| > 70°$ is 600 units only. This is confirmed by TD-1 observations.[28] Carruthers and Page (this workshop) studied Apollo 16 photographs, which resolve considerably fainter stars than do the TD-1 observations. Fainter stars are estimated,[19] however, to contribute less than 30 units.

Galactic Corona

Jakobsen and Paresce point out that ultraviolet line emission may be present, at high galactic latitudes, from a hot (10^5–10^6 K) galactic corona.[53] They predict the intensity to be quite low, but they warn that the parameters of their calculation are quite uncertain.

Galaxies

Measurements of the integrated far-ultraviolet brightness of individual galaxies are surprisingly fragmentary.[33-36] Several integrations of the expected contribution due to galaxies are available,[19,37] including the careful assessment by Code (this

workshop). All agree that the observed signal is at least a factor of two above what is expected from the integrated light of galaxies.

Instrumental Noise

Instrumental noise originates in dark current, general scattered light, and grating-scattered Lα.

Grating-Scattered Lα

The geocorona multiply scatters solar Lα photons to the night side of the earth, resulting in a sky that, from rocket or satellite altitude, is very bright at 1216 Å. Even interplanetary spacecraft see a sky that is still quite bright at Lα because interstellar hydrogen flowing through the solar system also scatters solar Lα photons. This bright emission line is weakly scattered to all wavelengths by the (imperfect) grating. This affects certain experiments,[25,29,38] but is completely eliminated from others by a filter that excludes Lα.[11,37] Presence of Lα, while extremely undesirable, is not fatal, as the amount of grating scatter can be measured in the laboratory or (preferably) in flight.

General Scattered Light

For instruments that are in sunlight, careful baffling is required.[39]

Dark Current

Detectors of far-ultraviolet radiation can have very low dark currents. On the other hand, a space environment can produce unexpectedly high backgrounds[29] due to cosmic rays,[40] and, also, for earth-orbiting experiments, extremely highly time-variable particle backgrounds. This last effect means that sounding rockets and interplanetary experiments have a large advantage over earth-orbiting experiments, if dark count is a problem at all. Whether dark count is a problem depends on the instrument throughput. For a system with an efficiency (mirror reflectances, grating efficiency, detector quantum efficiency) of 1%, an error in the dark count rate of 1 count per second will produce a spurious background $S = 100/A\Omega\Delta\lambda$ units, where Ω is the system field of view in steradians, A the telescope primary area in cm^2, and $\Delta\lambda$ the bandpass in Å. The larger the value of S, the greater the concern must be over the value, and the variability, of the dark count rate.

Field of View

Naively, it would appear that one wants to have as small a field of view, Ω, as possible in a cosmic background radiation experiment, in order to exclude stars, and, of course, simultaneously increasing collecting area to maintain throughput. This is a conception, however, that is short-sighted, if not incorrect. The surface brightness of stars and other point sources within 20° of the galactic poles is only ~500 units at 1565 Å, as predicted by star catalogue integrations[11] and as measured by TD-1,[28] i.e., less than twice the lowest diffuse cosmic background that has been reported.[29] This means that an experiment with a huge 40° diameter fov, observing the poles, would only need a quite crude estimate of the brightness of the stars in the far ultraviolet in order to obtain a fairly secure measurement of the diffuse background. The point is that a large field of view is very forgiving, of even quite large errors in the brightnesses of individual stars, of incompleteness in lists of stars used for correction, and of uncertainty in pointing direction. The Apollo 17 experiment (12° × 12° field of view) observed both poles.[29] The stellar signal in the field of view, estimated from integration of calibrated star catalogues, varies from only 500 units at 1680 Å to ~0 at 1250 Å. In contrast, a small field of view is most unforgiving. In discussing the effects of Ω, I shall use 0.044 ster (12° × 12°),[25,29] 1.5×10^{-3} ster (2.5° FWHM),[11,41] and 8.5×10^{-6} ster (10′)[42] as examples. A 6.5^m unreddened A0 star accidentally omitted from the stellar correction generates (20, 580, 102 000) units of false background for a system with $\Omega = (0.044, 1.5 \times 10^{-3}, 8.5 \times 10^{-6})$ steradians. An 8.0^m unreddened B3 star omitted generates (62, 1830, 320 000) units of false background.

Of course, the smaller fov experiment will typically contain few bright stars; nonetheless, with an 8.5×10^{-6} ster fov, a 12.83^m unreddened A0 star omitted generates a false background of 300 units.

If an attempt is made, with a small fov experiment, to map the cosmic diffuse flux on the sky, pointing errors and errors in the magnitudes and spectral classes of stars in the fov, will lead to spurious "bright patches" in some locations and, of course, the number of these false patches will increase toward lower galactic latitudes because of the greater number of stars present there. A small field of view can be dangerous!

The Observations

The fact that the existing observations are in such serious disagreement indicates that most of them (or even all of them) are wrong or defective in some way. Three general remarks concerning experiments in this field are therefore in order. First, given the circumstances, it is crucial that every detail of the experiment, the data processing, and the analysis be published. Otherwise, a critical assessment is not possible, and the publications represent no more than claims. Second, all the data should be published, including data that were excluded from analysis for various reasons. Again, otherwise, critical assessment is stymied. Finally, P. D. Feldman and G. H. de Vaucouleurs (this workshop) both emphasize that the coordinates of claimed bright and dark spots on the sky should be published, so that detailed consistency of results between completely different experiments can be tested. None of the observers claiming bright, patchy distributions on the sky have published detailed information on the coordinates of the patches.[11,41,44,50]

A brief review cannot hope to critically analyze the observations and separate the wheat, if any, from the chaff. Thus, I will simply point a finger, in every case, toward elements in the given experiment that should be considered sharply by readers making their assessments of the original papers. Certain specific information concerning many

of the experiments referenced is given in Table 1. Generally speaking, the smaller the field of view Ω, the more sensitive the experiment is to the stellar correction (if the stellar correction is significant at all); knowledge of the precise pointing direction and the accurate brightness of each and every star in the field of view become more and more critical. Also, the larger the value of the parameter S, the more precisely one must know the dark count rate and the greater the concern over a time-variable dark count rate (the dark count rate is usually most variable in earth-orbital experiments).

OAO-2[42,44]

The field of view was tiny (8.5×10^{-6} ster), and dark current was time-variable. The claimed residual is very patchy, with both bright and dim patches at low latitudes.

Table 1

Parameters of Some Ultraviolet Background Experiments

Experiment	References	Ω (ster)	A (cm²)	$\Delta\lambda$ (Å)	$S = \frac{100}{A\Omega\Delta\lambda}$	Orbit*
Apollo-Soyuz	11, 41	1.5×10^{-3}	1,075	90	0.7	O
Astro 7	22, 49	1.2×10^{-3}	201	400	1	R
Aries A-8	37	2.5×10^{-3}	60	60	11	R
TD-1	45, 46	1.7×10^{-5}	594	400	25	O
Aerobee	47, 48	2×10^{-2}	0.62	180	45	R
OAO-2	42, 44	8.5×10^{-6}	324	270	132	O
Apollo 17	25, 29	4.4×10^{-2}	1.14	11	181	I
D2B-Aura	24, 43, 50	8.4×10^{-4}	0.64	330	555	O
Voyager	54	2.6×10^{-5}	21.2	30	5880	I

*O = earth-orbiting, R = sounding rocket, I = interplanetary.

TD-1[45,46]

The field of view was very small (1.7×10^{-5} ster), and time-variable dark current was a serious problem. At 1550 Å, particle background was the minimum: 0.11 to 0.84 counts s^{-1} (higher values were present but were excluded from analysis). Some Lα contamination was present. A nonpatchy residual, which varies with galactic latitude, is reported.

Voyager[54]

The field of view was very small (2.6×10^{-5} ster), the pointing system jitter was 0.5°, and heavy Lα contamination was present. No attempt to determine the high-latitude background could be made.

D2B-Aura[21,43,50]

The field of view was quite small (8.4×10^{-4} ster). The altitude varied between 500 and 700 km. Dark current was 50 counts s^{-1}. A patchy residual of 500–3000 units is reported at 1690 Å, correlated with galactic latitude.

Astro 7[22,49]

The field of view was small (1.2×10^{-3} ster). Peak altitude was 254 km. A high (2500 units) diffuse background is reported at 1800 Å for $b = 60°$. Concern is expressed regarding airglow (private communication in connection with the present workshop).

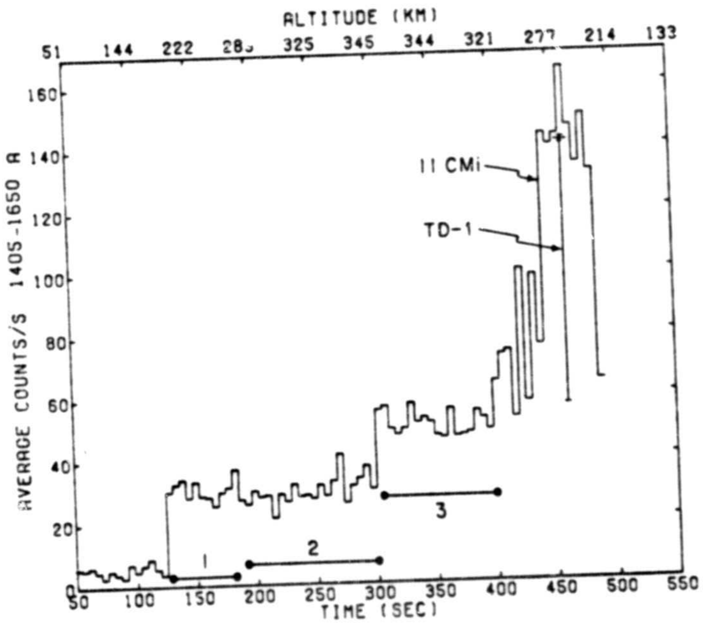

FIGURE 6. In-flight calibration of the Aries A-8 experiment.[37] The Aries A-8 observation of 11 C Mi agrees well with the TD-1 observation.

Apollo-Soyuz[11,41]

The field of view was small (1.5×10^{-3} ster). Large numbers of extremely bright (2000–8000 units) patches are reported in the first paper, but no observations of intensities greater than 2000 units are mentioned in the second paper.

Aries A-8[37]

The field of view was small (2.5×10^{-3}). The rocket's peak altitude was 347 km. A low (300 units) background was reported at three locations where Apollo-Soyuz reported ~1000 units.[41] Additional data verifying the Aries A-8 calibration is given in FIGURES 5 and 6. The photometric data were contaminated with effluent from another experiment[37] or from the Aries rocket motor,[51] but the spectrometric data show no sign of contamination.

Aerobee[47,48]

The field of view was moderate (2×10^{-2} ster). The pointing uncertainty was ~1°. The rocket altitude was only 200 km. A high (1000–2000 units) signal at the north galactic pole is attributed to airglow, but only on the basis of disagreement with other observations.[29]

Apollo 16

Henry *et al.* (this workshop) examined far-ultraviolet electronographic photographs taken from the surface of the moon.[52] The field of view was 20° and the resolution was ~2′. High (2000–4000 units) uniform backgrounds were seen at high latitudes. There is evidence for general instrumental scattered light in some photographs.

Prognoz[38]

The field of view was 6° × 6°. The altitude was as high as 200 000 km. Lα contamination was present, but motion through the geocorona could be used to accurately assess the effect. A low celestial background (~400 units) is reported.

Apollo 17[25,29,32,39]

The field of view was large (4.4×10^{-2} ster), so the stellar correction was small and was insensitive to uncertainties in pointing direction or in knowledge of the brightnesses of the stars. The dark count was high (27.6 counts s^{-1}) but was very well determined (to ±0.1 count s^{-1}) and was entirely independent of time during the trans-earth coast. Substantial grating-scattered Lα was present at all wavelengths, but could be accurately assessed by using the earth as a powerful Lα source. Airglow was not a problem, as the observations were made about halfway between the earth and the moon.

SUMMARY

In FIGURE 7, I show the spectrum of the cosmic background at high galactic latitudes.[37] The minimum intensity of 300 units at 1400 Å seems secure,[11,29,37] but the

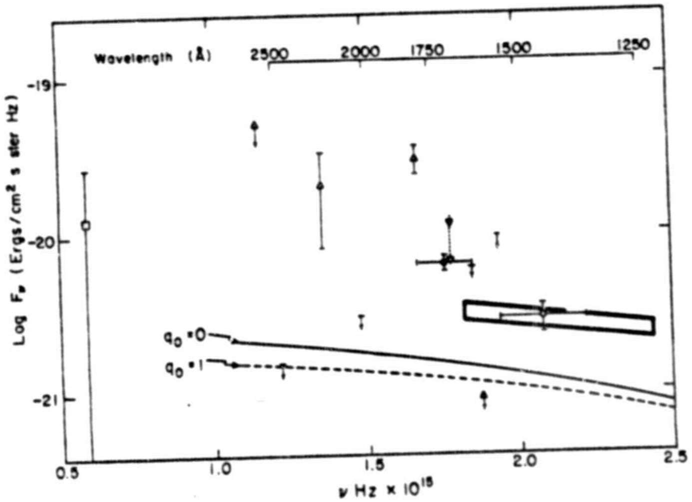

FIGURE 7. A summary of the observations of the high galactic latitude cosmic ultraviolet background radiation spectrum.[17] Observations are indicated by a filled circle and a heavily outlined region,[17] a circle,[11,41] a filled triangle,[29] open triangles,[49] inverted triangles,[43,50] and dashes, which are upper limits.[42] The solid and dashed lines represent estimates of the contribution from the integrated light of galaxies[37] for both an open ($q_o = 0$) and a closed ($q_o = 1$) universe.

intensity at 1700 Å is very uncertain (~0 to 2000 units). Conclusions concerning the meaning of structure in the spectrum are premature in the light of the variety of sources of line emission that might be present.

REFERENCES

1. FIELD, G. B. & R. C. HENRY. 1964. Free-free emission by intergalactic hydrogen. Astrophys. J. **140:** 1002.
2. FIELD, G. B. & S. C. PERRENOD. 1977. Constraints on a dense hot integalactic medium. Astrophys. J. **215:** 717.
3. KURT, V. G. & R. A. SUNYAEV. 1970. The ultraviolet background (intergalactic gas, the galaxy, and subcosmic rays). *In* Ultraviolet Stellar Spectra and Related Ground-Based Observations. L. Houziaux and H. E. Butler, Eds.: 341. D. Reidel Publishing Co. Dordrecht.
4. WEYMANN, R. 1967. Possible thermal histories of intergalactic gas. Astrophys. J. **147:** 887.
5. SHERMAN, R. D. & J. SILK. 1979. Cosmic far-ultraviolet background radiation: probe of a dense hot intergalactic medium? Astrophys. J. **231:** L61.
6. SHERMAN, R. D. 1979. Theory of the intercluster medium. Astrophys. J. **232:** 1.
7. SHERMAN, R. D. 1980. Cold dense photoionized universes. Astrophys. J. **237:** 355.
8. SHERMAN, R. D. 1980. Quasi-stellar objects in the intergalactic medium: source for the cosmic x-ray background? Astrophys. J. **238:** 794.
9. SHERMAN, R. D. 1980. QSO evolution and the intergalactic medium. Astrophys. J. **240:** 737.
10. JAKOBSEN, P. 1980. On the extragalactic nature of the far-ultraviolet background. Astron. Astrophys. **81:** 66.

11. PARESCE, F., C. F. MCKEE & S. BOWYER. 1980. Galactic and extragalactic contributions to the far-ultraviolet background. Astrophys. J. **240:** 387.
12. SHULL, J. M. & J. SILK. 1979. Model emission spectra from primeval galaxies. Astrophys. J. **234:** 427.
13. PARTRIDGE, R. B. & P. J. E. PEEBLES. 1967. Are young galaxies visible? II. The integrated background. Astrophys. J. **148:** 377.
14. TINSLEY, B.M. 1978. The extragalactic background light and slow star formation in galaxies. Astrophys. J. **220:** 816.
15. DE RÚJULA, A. & S. L. GLASHOW. 1980. Galactic neutrinos and UV astronomy. Phys. Rev. Lett. **45:** 942.
16. STECKER, F.W. 1980. Have massive cosmological neutrinos already been detected? Phys. Rev. Lett. **45:** 1460.
17. KIMBLE, R., S. BOWYER & P. JAKOBSEN. 1980. Astrophysical constraints on the radiative lifetime of neutrinos with mass between 10 and 100 eV/c^2 Phys. Rev. Lett. **46:** 80.
18. DAVIDSEN, A. F., S. BOWYER & M. LAMPTON. 1974. Cosmic far ultraviolet background. Nature (London) **247:** 513.
19. PARESCE, F. & P. JAKOBSEN. 1980. The diffuse UV background. Nature (London) **288:** 119.
20. HUFFMAN, R. E., F. J. LEBLANC, J. C. LARRABEE & D. E. PAULSEN. 1980. Satellite vacuum ultraviolet airglow and auroral observations. J. Geophys. Res. **85:** 2201.
21. MAUCHERAT-JOUBERT, M., P. CRUVELLIER & J. M. DEHARVENG. 1979. Ultraviolet observation of the zodiacal light from the D2B-Aura satellite. Astron. Astrophys. **74:** 218.
22. PITZ, E., C. LEINERT, A. SCHULZ & H. LINK. 1978. Ultraviolet zodiacal light observed by the Astro 7 rocket experiment. Astron. Astrophys. **69:** 297.
23. MARKKANEN, T. 1979. Polarization measurements and extinction near the north galactic pole. Astron. Astrophys. **74:** 201.
24. SANDAGE, A. 1976. High-latitude reflection nebulosities illuminated by the galactic plane. Astron. J. **81:** 954.
25. HENRY, R. C., R. C. ANDERSON, P. D. FELDMAN & W. G. FASTIE. 1978. Far-ultraviolet studies. III. A search for light scattered at large angles by dust. Astrophys. J. **222:** 902.
26. CARRUTHERS, G. R. & C. B. OPAL. 1977. Far-ultraviolet imagery of the Barnard Loop nebula. Astrophys. J. **212:** L27.
27. HENRY, R. C. 1981. Far-ultraviolet diffuse galatic light. Astrophys. J. **244:** L69.
28. GONDHALEKAR, P. M., A. P. PHILLIPS & R. WILSON. 1980 Observations of the interstellar ultraviolet radiation field from the S2/68 sky-survey telescope. Astron. Astrophys. **85:** 272.
29. HENRY, R. C., P. D. FELDMAN, W. G. FASTIE & A. WEINSTEIN. 1978. Far-ultraviolet studies. IV. Spectroscopy of north and south galactic pole regions observed from *Apollo* 17. Astrophys. J. **223:** 437.
30. WITT, A. N. 1977–1978. The Merope nebula revisited: The phase function of dust grains in the ultraviolet. Publ. Astron. Soc. Pac. **89:** 750.
31. HENRY, R. C. 1977. Far-ultraviolet studies. I. Predicted far-ultraviolet intersteller radiation field. Astrophys. J. 33: 451.
32. HENRY, R. C., A. WEINSTEIN, P. D. FELDMAN, W. G. FASTIE & H. W. MOOS. 1975. Low-resolution ultraviolet spectroscopy of several hot stars observed from Apollo 17. Astrophys. J. **201:** 613.
33. CARNOCHAN, D. J., C. NAVACH & R. WILSON. 1975. The ultraviolet fluxes from some nearby galaxies. Mon. Not. R. Astron. Soc. **172:** 27P.
34. HENRY, R. C., P. D. FELDMAN & W. G. FASTIE. 1976. Apollo 17 far-ultraviolet spectra in the Large Magellanic Cloud. Astron. Astrophys. **53:** 317.
35. CODE, A. D. & G. A. WELCH. 1979. Ultraviolet photometry from the Orbiting Astronomical Observatory. XXVI. Energy distributions of seven early-type galaxies and the central bulge of M31. Astrophys. J. **228:** 95.
36. CARNOCHAN, D. J., K. NANDY & D. H. MORGAN. 1979. Ultraviolet observations of the spiral galaxy M33, NGC598. Mon. Not. R. Astron. Soc. **189:** 763.
37. ANDERSON, R. C., R. C. HENRY, W. H. BRUNE, P. D. FELDMAN & W. G. FASTIE. 1979.

Far-ultraviolet studies. V. Rocket observation of the diffuse cosmic background. Astrophys. J. **234:** 415.

38. Hua, C. T., P. Cruvellier, G. Courtes, A. M. Zvereva, L. V. Granitsky & A. B. Severny. 1979. Far UV spectrum of the sky background and geocorona observed by Galactika aboard the Prognoz-6 satellite. *In* (COSPAR) X-Ray Astronomy. W. A. Baity and L. E. Peterson, Ed. 7: 551. Pergamon Press. Oxford, England.
39. Fastie, W. G. 1973. The Apollo 17 far-ultraviolet spectrometer experiment. Moon 7: 49.
40. Viehmann, W., A. G. Eubanks, G. F. Pieper & J. H. Bredekamp. 1974. Goddard Spaceflight Center document X-755-74-210.
41. Paresce, F., B. Margon, S. Bowyer & M. Lampton. 1979. Observations of the cosmic background radiation at 1440 angstroms. Astrophys. J. **230:** 304.
42. Lillie, C. F. 1972. The extragalactic component of the ultraviolet sky brightness. *In* The Scientific Results from the Orbiting Astronomical Observatory (OAO-2). A. D. Code. Ed.: 583. NASA. Washington, D. C.
43. Maucherat-Joubert, M., P. Cruvellier & J. M. Deharveng. 1978. Far UV radiation background at high galactic latit... from the D2B-Aura satellite. Astron. Astrophys. **70:**467.
44. Lillie, C. F. & A. N. Witt. 1976. Ultraviolet photometry from the Orbiting Astronomical Observatory. XXV. Diffuse galactic light in the 1500–4200 Å region and the scattering properties of interstellar dust grains. Astrophys. J. **208:** 64.
45. Morgan, D. H., K. Nandy & G. I. Thompson. 1976. Mon. Not. R. Astron. Soc. **177:** 531.
46. Morgan, D. H., K. Nandy & G. I. Thompson. 1978. Ultraviolet observations of the diffuse galactic light from the S2/68 sky-survey telescope. Mon. Not. R. Astron. Soc. **185:** 371.
47. Henry, R. C. 1973. Ultraviolet background radiation. Astrophys. J. **179:** 97.
48. Henry, R. C., J. R. Swandic, S. D. Shulman & G. Fritz. 1977. Far-ultraviolet studies. II. Galactic-latitude dependence of the 1530 Å interstellar radiation field. Astrophys. J. **212:** 707.
49. Pitz, E., C. Leinert, A. Schulz & H. Link. 1979. Rocket photometry of ultraviolet galactic light. Astron. Astrophys. **72:** 92.
50. Maucherat-Joubert, M., J. M. Deharveng & P. Cruvellier. 1980. The nature of the UV radiation background. Astron. Astrophys. **88:** 323.
51. Price, S. D., T. L. Murdock, A. McIntyre, R. E. Huffman & D. E. Paulsen. 1980. On the diffuse cosmic ultraviolet background measured from Aries A8. Astrophys. J. **240:** L1.
52. Page, T., G. R. Carruthers & R. Hill. 1978. S201 Catalog of far-ultraviolet objects. NRL Report 8173.
53. Jakobsen, P. & F. Paresce. 1981. Interstellar hot plasma contributions to the diffuse ultraviolet background. Astron. Astrophys. In press.
54. Sandel, B. R., D. E. Shemansky & A. L. Broadfoot. 1979. Observations of the diffuse interstellar EUV radiation field. Astrophys. J. **227:** 808.

Appendix

Papers Presented at the Workshop on Ultraviolet Background Radiation

1. The UV Background and Massive Cosmological Neutrinos. F. W. Stecker (Goddard Space Flight Center).
2. Night Airglow, 1250–3000 Å. R. E. Huffman (Air Force Geophysics Laboratory).
3. Direct Starlight Contribution to the Galactic Ultraviolet Radiation Field from Apollo 16 Observations. G. R. Carruthers (Naval Research Laboratories) and T. Page (NASA-JSC).
4. Scattering Properties of Interstellar Grains. A. N. Witt (University of Toledo).

5. The Ultraviolet Phase Function of Interstellar Grains. M. Jura (University of California, Los Angeles) and W. H. Smith (Washington University).
6. Ultraviolet Brightness of Galaxies. A. D. Code (University of Wisconsin).
7. Constraints from Astronomical Photon Backgrounds on the Radiative Lifetime of Neutrinos. R. Kimble, S. Bowyer, and P. Jakobsen (University of California, Berkeley).
8. Far Ultraviolet Observations of Sky Background aboard the Prognoz-6 Satellite. C. T. Hua, P. Cruvellier, and G. Courtes (CNRS, France) and A. Zvereva and A. Severny (Crimean Observatory, USSR).
9. Apollo 16 Limits on Ultraviolet Background Radiation. R. C. Henry (Johns Hopkins University), G. C. Carruthers (Naval Research Laboratory), and T. Page (NASA-JSC).
10. The Far UV Background—The Berkeley Perspective. S. Bowyer (University of California, Berkeley).
11. Far Ultraviolet Background: Aries and Apollo 17 Results. R. C. Henry (Johns Hopkins University).